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Dietary Restrictions in Dialysis Patients: Is There Anything Left to Eat?

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Abstract

A significant number of dietary restrictions are imposed traditionally and uniformly on maintenance dialysis patients, whereas there is very little data to support their benefits. Recent studies indicate that dietary restrictions of phosphorus may lead to worse survival and poorer nutritional status. Restricting dietary potassium may deprive dialysis patients of heart-healthy diets and lead to intake of more atherogenic diets. There is little data about the survival benefits of dietary sodium restriction, and limiting fluid intake may inherently lead to lower protein and calorie consumption, when in fact dialysis patients often need higher protein intake to prevent and correct protein-energy wasting. Restricting dietary carbohydrates in diabetic dialysis patients may not be beneficial in those with burnt-out diabetes. Dietary fat including omega-3 fatty acids may be important caloric sources and should not be restricted. Data to justify other dietary restrictions related to calcium, vitamins and trace elements are scarce and often contradictory. The restriction of eating during hemodialysis treatment is likely another incorrect practice that may worsen hemodialysis induced hypoglycemia and nutritional derangements. We suggest careful relaxation of most dietary restrictions and adoption of a more balanced and individualized approach, thereby easing some of these overzealous restrictions that have not been proven to offer major advantages to patients and their outcomes and which may in fact worsen patients' quality of life and satisfaction. This manuscript critically reviews the current paradigms and practices of recommended dietary regimens in dialysis patients including those related to dietary protein,

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KKZ has received honoraria from Abbott, Abbvie, Fresenius, Keryx, Shire, Vifor, and other manufacturers of phosphorus binders, nutritional supplements, or medications and items related to dialysis patients.

carbohydrate, fat, phosphorus, potassium, sodium, and calcium, and discusses the feasibility and implications of adherence to ardent dietary restrictions.

Keywords

Dietary restriction; dietary protein intake; dietary load; nutritional management; outcomes

Dietary counseling and nutritional interventions are quintessential components in the management of chronic kidney disease (CKD) patients, including those who receive maintenance dialysis therapy. To that end, in the United States it is a regulatory requirement for an outpatient dialysis clinic to have an on-site registered dietitian to provide dietary monitoring and counseling to all dialysis patients.[1] Both dietitians and nephrologists often impose a number of dietary restrictions on their patients related to dietary phosphorus, potassium, sodium, fluid intake, and macronutrients including carbohydrate and fat. Dietitians also emphasize the importance of high dietary protein intake in dialysis patients, while they may also recommend weight loss efforts in patients with morbid obesity who are not yet eligible for kidney transplant wait-listing.[2] Eating or not eating during hemodialysis treatment is another controversy; in the United States many dialysis centers prohibit food intake during dialysis treatment, while in other countries meals are proactively served to dialysis patients.[3]

Many of these dietary recommendations for dialysis patients are highly restrictive (see Table 1), and the task of finding anything permissible to eat is a major challenge for dialysis patients. Indeed, many of these dietary restrictions such as a low potassium diet contradict the current recommendations for a heart-healthy diet.[4] It is not an exaggeration to say that the dialysis dietary regimen is among the most restrictive diets, and these restrictions may render many patients frustrated and lead to suboptimal adherence and compliance. In this manuscript some of these dietary recommendations and restrictions are critically reviewed and their impact on dialysis patient outcomes and recommendations for future research discussed.

Dietary Protein Recommendations

Non-dialysis dependent (NDD) CKD patients are generally advised to eat lower amounts of protein. The so-called low protein diet (LPD) that is often recommended for non-diabetic, NDD-CKD Stages 3b, 4 and 5 (eGFR<45 ml/min/1.73 m^2 BSA) targets a daily dietary protein intake of ~0.6 g/kg/day, i.e., 35 to 45 g of total daily protein for a 60 to 70 kg person.[5] The LPD is significantly lower than what the non-vegetarian general population in the USA and most Western countries eat, i.e., 0.9 to 1.1 g/kg/day. Furthermore, the Institute of Medicine “Food and Nutrition Board” recommends a daily dietary protein intake of 0.8 g/kg/day in the general population, which is 0.2 g/kg/d above the minimum dietary protein requirement, offering a safety cushion against protein-energy malnutrition.[5, 6] The so-called very low protein diet (vLDP) consists of only 0.3 g/kg/day and is also recommended for very late stage NDD-CKD; it invariably needs to be supplemented by either essential amino acids or their keto-analogues.[5, 7]

Notwithstanding the ongoing discussion about the safety, adequacy and effectiveness of the LPD or supplemented vLPD for NDD-CKD patients, for those who transition to dialysis treatment the guidelines are relatively consistent in that the recommended dietary protein intake range is to be 1.2 to 1.4 g/kg/day, which is 2-times higher than the LPD and even higher than what the general population eats. This poses a major challenge for the successful transition from NDD-CKD to dialysis therapy, especially since many of these patients, who were used to LPD, need to undergo significant re-education and acculturation. In reality, over half of dialysis patients have inadequate dietary protein [<1.0 g/kg/day as measured by the normalized protein nitrogen appearance (nPNA) also known as normalized protein catabolic rate (nPCR)] as shown in a recent study by Shinaberger at al,[8] (Figure 1). The estimates of nPNA or nPCR are calculated by urea kinetic modeling.[8–10] As to whether such a high protein intake of 1.2–1.4 g/kg/day is useful or not, observational studies including those by Kalantar-Zadeh et al.,[9] Shinaberger et al.,[8] and Ravel et al.,[10] have suggested superior hospitalization and survival outcomes, although there has never been any controlled trial to corroborate these dietary targets. According to Shinaberger et al.,[8] the best survival in 53,933 hemodialysis patients was achieved when the nPCR was in the 1.2–1.4 g/kg/day range (Figure 2).

A high protein intake of ~1.2 g/kg/day poses additional challenges including a somewhat high dietary phosphorus and potassium load, higher risk of metabolic acidosis, and higher probability of increased fluid intake by virtue of the need for larger food volume (Figure 3).[11] Nevertheless, since the advantages of higher dietary protein intake may outweigh its potential challenges in thrice-weekly hemodialysis patients, they should be consistently reminded and educated during rounds to increase their dietary protein intake including consumption of more meat, fish, eggs and poultry as well as fruits and vegetable high in protein such as legumes and tofu based foods. If such interventions are inadequate, then meals during dialysis should be provided with high protein content[3] and high protein oral nutritional supplements should be offered.[6] Meals and supplements during hemodialysis treatment is a separate topic and beyond the scope of this review article.[3, 6]

Dietary Phosphorus Restrictions

Counseling on dietary phosphorus and monitoring patients' phosphorus intake are perhaps the most time-consuming tasks of dialysis clinic dietitians in the United States and many other countries.[12, 13] Nevertheless, recent data examining the impact of dietary phosphorus counseling efforts on dialysis patient outcomes have questioned the wisdom of this several decade-old paradigm, supported by the notion that restricting dietary protein intake via traditional approaches can invariably lead to lower dietary protein intake and hence may increase the risk of protein-energy wasting and death.[14] In a recent study by Lynch et al.,[15] the impact of prescribed dietary phosphorus restrictions on long-term survival was examined in 1,751 hemodialysis patients using marginal structural models to adjust for longitudinal confounding. The study found that more restrictive prescribed dietary phosphorus was associated with poorer indices of nutritional status and that there was an incrementally greater survival with more liberal dietary phosphorus prescription; in particular, those who were prescribed >1000 mg/day dietary phosphorus or no dietary restriction had 27% and 29% greater survival, respectively.[15]

In another study, Shinaberger et al.[14] reported on 30,075 prevalent hemodialysis patients in the USA; in comparison to patients whose serum phosphorus and dietary protein intake both rose over 6 months, those whose serum phosphorus decreased but whose protein intake increased had 10% greater survival, whereas those whose phosphorus increased but whose dietary protein decreased or those whose phosphorus and dietary protein intake concomitantly decreased had 11% and 6% worse mortality, respectively.[14]

Both old and new data have been relatively consistent in showing that a low serum phosphorus level, e.g. <3.5 mg/dL, is associated with higher mortality independent of age[16] and other confounders.[17] To that end, adherence to KDIGO's guidelines of "normalization" of serum phosphorus, which may mean targeting levels even below 3.5 mg/dL in dialysis patients, is a challenging dilemma.[18] Hence, prescribed dietary phosphorus restriction may not be associated with improved survival among hemodialysis patients if it results in inadequate protein intake, and heightened dietary phosphorus restrictions may be associated with greater mortality, such that the risk of controlling serum phosphorus by restricting dietary protein intake may outweigh the benefits and lead to greater mortality in dialysis patients.[14, 15]

It is important to note, however, that in a study using Food Frequency Questionnaires in a cohort of 224 hemodialysis patients over 5 years., Noori et al.[19] showed that higher dietary phosphorus intake and higher dietary phosphorus to protein (P-to-P) ratios were each associated with increased death risk even after adjustments for serum phosphorus, phosphorus binders and their classes, dietary protein, energy, and potassium intake (Figure 4). In this study, dietary P-to-P ratios of 14 to <16, and ≥16 mg/g were associated with 80% and 99% higher death risk, respectively, compared to those who ate food with a P-to-P ratio of <14 mg/g.[19] Hence, the choice of type of protein that has lower P-to-P ratio such as egg whites may have a bearing on survival.[13]

Do recent studies suggest that we should abandon any type of dietary phosphorus restriction in dialysis patients? There is little doubt that hyperphosphatemia is associated with poorer outcomes in CKD.[20] The aforementioned studies offer important opportunities to re-channel dietary counseling efforts into the correct direction with greater focus on understanding and identifying the sources of added phosphorus in processed foods[21] and better appreciating that natural (organic) phosphorus is not well absorbed, e.g. approximately 40–60% of phosphorus from animal protein and <40% of plant-based protein is usually absorbed through the GI tract, whereas the added or inorganic phosphorus is almost 100% absorbable.[17, 21, 22] Hence, the incorrect practice of frightening dialysis patients in order to avoid natural sources of protein that may also have high phosphorus content (such as meat, poultry, fish, eggs, natural dairy products, and legumes) should be discouraged.

We believe that dietitians should spend more time and effort on educating dialysis patients on how to: (1) identify added phosphorus in processed foods in order to avoid them,[23] (2) choose natural sources of proteins with the lowest phosphorus-to-protein ratio such as egg whites;[24] and (3) take phosphorus binders correctly and diligently, including avoidance of consuming binders on an empty stomach (e.g. before meals), and adjustment of binder dose based on the binder potency and in particular based on the estimated amount of phosphorus

in each meal.[12] To give blind phosphorus binder prescriptions to dialysis patients with a fixed number of pills "per meal" without providing first such fundamental education about types of dietary phosphorus or without educating the proper use of phosphorus binders is indeed an incorrect approach adopted by many professional caring for dialysis patients and should be reexamined.[12] Additional studies including randomized controlled trials should examine whether non-dietary control of phosphorus or restriction of non-protein sources of phosphorus is safe and more effective, keeping in mind that hyperphosphatemia is not merely a reflection of dietary phosphorus intake but of also many other factors including hyperparathyroidism.[25, 26]

Dietary Potassium Restrictions

Dietary potassium restrictions are often implemented during earlier stages of CKD when patients are still non-dialysis dependent, and are reinforced in the majority of patients transitioning to ESRD, particularly in hemodialysis patients. A recent cohort study over 3 years in 81,013 prevalent hemodialysis patients suggested that the best pre-hemodialysis serum potassium range associated with the greatest survival was 4.6 to 5.3 mEq/L, whereas potassium levels <4.0 or ≥5.6 mEq/L were associated with increased mortality.[27] Another clinically relevant finding in this study was that serum potassium correlated closely with nutritional markers, in particular nPCR (nPNA) suggesting that patients who eat more protein also tend to have higher serum potassium level (Figure 5).[27] In a more recent cohort study that examined the mortality of hyperkalemia in 111,651 hemodialysis and 10,468 peritoneal dialysis patients, the latter group was 3.3 times more likely to have lower serum potassium <4.0 mEq/L, and their death risk was 51% and 52% higher with serum potassium levels <3.5 mEq/L and ≥5.5 mEq/L.[28] Hence, both hypo- and hyperkalemia appear to be harmful in dialysis patients irrespective of dialysis modality. It is important to note that the variability of serum potassium in dialysis patients is not the exclusive function of dietary potassium load and that several other factors such as potassium concentration in the dialysate bath or the dialysis treatment length and frequency play important roles.

A recent study by Noori et al.[29] examined the association between dietary potassium intake via Food Frequency Questionnaire[30] at the start of a 5-year cohort of 224 hemodialysis patients in Southern California and found that patients with higher potassium intake had greater dietary energy, protein, and phosphorus intake and higher pre-dialysis serum potassium and phosphorus levels. Greater dietary potassium intake was associated with increased mortality in survival models that were adjusted for nutritional factors including serum potassium and phosphorus levels, in that death risk of the 3 higher quartiles of dietary potassium intake were 1.4, 2.2 and 2.4 times higher than the lowest dietary potassium quartile.[29] Hence, higher dietary potassium load *per se*, independent of serum potassium, is incrementally associated with higher mortality.

These and other data have been used to justify strict dietary potassium restrictions in CKD and dialysis patients. However, it is important to appreciate that many potassium rich foods are considered "heart healthy" including fresh fruits and vegetables, fresh squeezed juices, legumes, and grains. [29] Hence, a low potassium diet falls outside of what is generally recommended as a healthy diet and life style, and such dietary restrictions may contribute to

the burden of cardiovascular disease in the CKD patient population according to several studies.[4, 31] We suggest educating patients regarding the different sources of potassium and empowering our patients to make choices which fall within the "heart healthy" category and avoid other sources of potassium so that they obtain the most benefit from a diet with moderate amounts of potassium. Hence in this case a relaxation of dietary potassium restriction and a more balanced and realistic approach to such overzealous restrictions would mean choosing the most beneficial sources of potassium which is only possible through a concerted education effort. The use of potassium binding resins for hyperkalemia control may also allow for more consumption of heart-healthy diets with less risk of hyperkalemia, although their intake can be limited by side effects and more studies are needed.[32] Newer resins, in development, may facilitate this approach.

Dietary Glycemic Restrictions and Carbohydrate Load

In the United States almost half of all new dialysis patients are diabetic, and many of them are automatically continued on the same dietary restrictions as non-CKD patients with diabetes.[33] Even though high glycemic burden is associated with poor outcomes in the dialysis population,[34–36] many diabetic dialysis patients develop a so-called "burnt-out diabetes" phenomenon, such that their insulin and oral hypoglycemic agents can be significantly decreased and at times need to be discontinued due to risk of hypoglycemia.[37–39] Indeed hemodialysis induced hypoglycemia is an under-recognized and widespread event that may happen even more frequently in diabetic dialysis patients.[40] Recent studies suggest that the best hemoglobin A1c target range for diabetic dialysis patients is 7 to 9% and that a lower A1c, especially <6% is associated with poor outcomes, which may be related to poor nutritional status or other metabolic derangements of uremia.[34, 37, 41–43] Hence, glycemic restrictions that are traditionally used in non-CKD diabetic patients may lead to harm in diabetic dialysis patients. We suggest that dietary glycemic restrictions in dialysis patients with A1c <7% be relaxed, and that among patients with higher A1c levels careful and balanced dietary recommendations be considered to assure the provision of at least 35 Cal/kg/day.[6]

Dietary Salt and Fluid Restriction

Whereas there are important data suggesting that high interdialytic weight gain is associated with higher death risk,[44] there are no convincing data to suggest that more dietary sodium restriction in dialysis patients has any bearing on outcomes. Indeed recent studies in the general population suggest that low salt intake is associated with poorer outcomes.[45] With regard to fluid restriction, a cohort study by Kalantar-Zadeh et al. in 34,107 hemodialysis patients showed that in unadjusted survival analyses, higher weight gain reflecting higher fluid intake was associated with better nutritional status including higher protein intake, serum albumin, and body mass index and tended to be linked to greater survival.[44] The higher fluid-gain increments were originally associated with better survival but after multivariate adjustment (including for nutritional status) it was associated with higher (not lower)death risk. This suggests that the benefit of fluid restriction is achieved only if optimal nutritional status and food intake is not compromised.[44] While we do not recommend complete relaxation of fluid and salt restrictions given the difficulties associated with

volume overload, we warn against overzealous salt and fluid restrictions in dialysis patients, especially in those with significant residual renal function and urine output, if such dietary restrictions would compromise the need for adequate protein and energy intake in these patients.

Dietary Fat Restrictions

Although it would seem intuitive to extrapolate the low dietary fat recommendations of the general population to dialysis patients, there are virtually no convincing data to suggest that restricting dietary fat has any advantage in this latter group. A surprising observation, not well known, is that total and LDL hypercholesterolemia, although very common in non-dialysis ambulatory outpatients, are substantially less prevalent in the dialysis population, although the prevalence of hypertriglyceridemia is nearly equivalent.[46] In comparative analyses of randomly selected hemodialysis patients in Southern California who were one-to-one randomly matched on gender, race/ethnicity, diabetes mellitus, and age (±5 years) to non-dialyzed outpatients from the same geographic area and whose lipid panels were measured in the same laboratory center, total cholesterol and LDL and HDL levels were −51, −39; −10 mg/dL lower, respectively, in hemodialysis patients than in control subjects even after adjustment for body mass index and statin use ($p<0.001$).[46] It is important to note that in most epidemiologic studies higher lipoprotein levels[47] or higher body fat[48] are associated with greater survival in dialysis patients, while associations with HDL are more complex;[49–51] hence, achieving higher circulating levels of lipoproteins and their dietary modulation may have favorable impact in dialysis patients.

In a randomized controlled study by Marckmann et al.[52] the effects of oral unsaturated fat supplements were examined in 40 Danish hemodialysis patients. Fat supplementation resulted in increased total energy intake of +380 Cal/day, a 9% greater intake of total energy attributed to dietary fat, and a +0.5 kg increase in weight, while serum C-reactive protein fell by 1.69 mg/L and there was no significant changes in blood lipids. These investigators concluded that dietary unsaturated fat have favorable nutritional benefits.[52] The anti-inflammatory benefits of higher dietary intake of certain fats has recently been shown in a 5-year cohort of hemodialysis patients, in whom lower dietary omega-6 to omega-3 ratio was associated with reduced inflammation over time and a trend toward lower death risk.[53] Hence, it is possible, although not yet proven, that dietary fat not only provides a good source of the needed calories, if properly administered it could also have additional benefits including dietary modulation of inflammation.[54]

Dietary Recommendations for Trace Elements and Vitamins

In addition to protein-energy wasting, dialysis patients may also suffer from deficiencies of micronutrients, particularly trace elements and vitamins. Common vitamin deficiencies observed in maintenance dialysis patients include vitamin C or ascorbic acid, vitamin B6 or pyridoxine, folate, and 1,25-dihydroxycholecalciferol or calcitriol, and trace element deficiencies may include iron, zinc, and selenium. In contrast, toxicities in dialysis patients may include aluminum and possibly copper.[55] Examining dietary recommendations for each of these vitamins and trace elements is beyond the scope of this review article. However, it

is important to note that in dialysis patients there is an abnormally high prevalence of antioxidant deficiency which can be engendered or aggravated by low intake of natural sources such as fresh fruits and vegetable given the imposed dietary restriction that may be associated with inadequate ingestion of antioxidant vitamins such as vitamins E, C, and carotenoids.[4, 31, 55]

Dietary Calcium Restrictions

With the emergence of calcium-free phosphorus binders and recent data on vascular calcification,[56–58] there has been a drastic change in the prevailing paradigm of maintaining positive calcium balance[59] and recommending low dietary calcium over the past 10–15 years.[60] Even though virtually all epidemiologic studies show higher death risk associated with high serum calcium levels >10.5 mg/dL, low serum calcium levels <8.5 mg/dL are also associated with higher mortality.[61] A high serum calcium level is not necessarily a result of a greater calcium load but may be related to other hormonal derangements including hyperparathyroidism.[62] The surge in use of calcimimetics[63, 64] may complicate the current recommendations pertaining to dietary calcium intake in dialysis patients; this is an area that begs future research.

In-Center Restrictions for Eating during Hemodialysis

In the United States and Canada there are significant restrictions for eating during hemodialysis treatment in dialysis clinics. Among the reasons to justify these restrictions are postprandial hypotension, aspiration risk, infection control and hygiene, dialysis staff burden, diabetes and phosphorus control, and financial constraints.[3] However in other countries such as Germany, Japan and many other Europeans and Asians nations, meals and meal trays are regularly prepared and served during each hemodialysis treatment session.[3] We believe that in carefully selected and monitored patients, in-center provision of high-protein meals and/or oral nutritional supplements during hemodialysis is a feasible, inexpensive, and patient-friendly strategy.[3] Given the fact that meals and supplements during hemodialysis would require only a small fraction of the funds currently used for dialysis patients this is also an economically feasible strategy.[3]

Racial Disparities and Diet

Several unique racial/ethnic disparities exist among hemodialysis patients, such that there is a 3.5 and 1.5 fold greater representation of African Americans and Hispanics, respectively, compared to non-Hispanic whites.[65, 66] For reasons that have remained vastly unexplainable, minority dialysis patients exhibit greater survival than non-Hispanic white dialysis patients.[67] African American dialysis patients are 15 to 20% less likely to die of cardiovascular [68] disease than whites especially those who are older than 50 years.[69] Recent data suggest that significant differences exist between African American and non-Hispanic and Hispanic white hemodialysis patients with regards to nutritional status, dietary intake and inflammation, and that these differences may contribute to racial survival disparities.[68, 70] In a 6-year cohort of 799 hemodialysis patients, the dietary intake of African Americans was higher in energy (+293 ±119 cal/day) and fat (+18±5 g/day) compared to whites.[68, 69] Whether or not minorities are less compliant with the dietary

restrictions, with subsequent better outcomes is a highly provocative hypothesis that remains to be examined in future studies.

Consequences of Dietary Restriction and Future Research Directions

It is not clear whether imposing the traditionally practiced dietary restrictions on dialysis patients contributes to improved outcomes. While some dietary restriction appear to be justifiable, it is possible, although not yet proven, that overzealous and extensive restrictions may lead to poor outcomes including worse survival by virtue of deteriorating the nutritional status and patients' health related quality of life, which is per se related to nutritional status.[71] There is little doubt that both dietary-nutritional and pharmacologic status of dialysis patients have overarching and long-lasting impact on patient survival even after successful kidney transplantation.[72] As stated above, a case-control study comparing dietary patterns of hemodialysis patients versus the general population suggested that dietary restriction in dialysis patients, including low potassium and phosphorus, leads to avoidance of most fresh fruits and vegetables and a more atherogenic diet with lower vitamin C, fiber, and carotenoid.[31] In a recent cross-sectional study by Koueiry et al.[4] using the "Dialysis Food Frequency Questionnaire,"[31] 97% of hemodialysis patients had lower than the recommended dietary fiber intake of 25 g/day or more. The study concluded that most dialysis patients did not meet the dietary guidelines for reducing the risk of cardiovascular disease.[4] Hence, reinforcing dietary restrictions on dialysis patients may contribute to atherosclerosis and increased cardiovascular morbidity and mortality.

Some nephrologists have noted that less compliant dialysis patients appear to live longer than the more compliant ones, an observation that may have some roots in the aforementioned dietary restrictions. Whereas we warn against over-interpretation of anecdotal observations, we cannot dismiss the plausible hypothesis that adhering to severe dietary restrictions may cause more harm than benefit, no matter how provocative it may sound. Many dietitians are under pressure by dialysis companies to achieve lower averaged phosphorus and potassium values in their dialysis units, and this may lead to the risky practice of hounding patients to eat less in an effort to improve arbitrary numbers. It is time to revisit the role of dietitians and nephrologists in the dialysis units and to re-examine current practices,[1] so that their approach to dietary counseling of dialysis patients may be consistent with most recent data such as those by Lynch et al.[15] and Shinaberger et al.,[14] which suggest that mere dietary restrictions may be detrimental.

Given the significant knowledge gap discussed above, there is a pressing need for high impact research with immediate clinical applicability in the nutritional management of dialysis patients. Several relevant questions for future research in this area are the following: What are the real impact of restricting dietary potassium, phosphorus, calcium and salt on clinical outcomes? What is the best dietary protein range upon transition to dialysis therapy? Should the recommended "low" protein diet for advanced CKD prior to ESRD be continued for less frequent and incremental hemodialysis regimen including those who receive only once or twice weekly hemodialysis therapy[73–77] as compared to thrice-weekly or more frequent hemodialysis? What types of high biological value proteins including plants vs. animal based foods can be recommended as better sources of low phosphorous diet?

Additional research on the potential of a more liberalized dietary approach on patient-centered outcomes would be relevant as well. Overall the benefits and harms of the decade-long practiced dietary restrictions are widely unknown and need urgent research.

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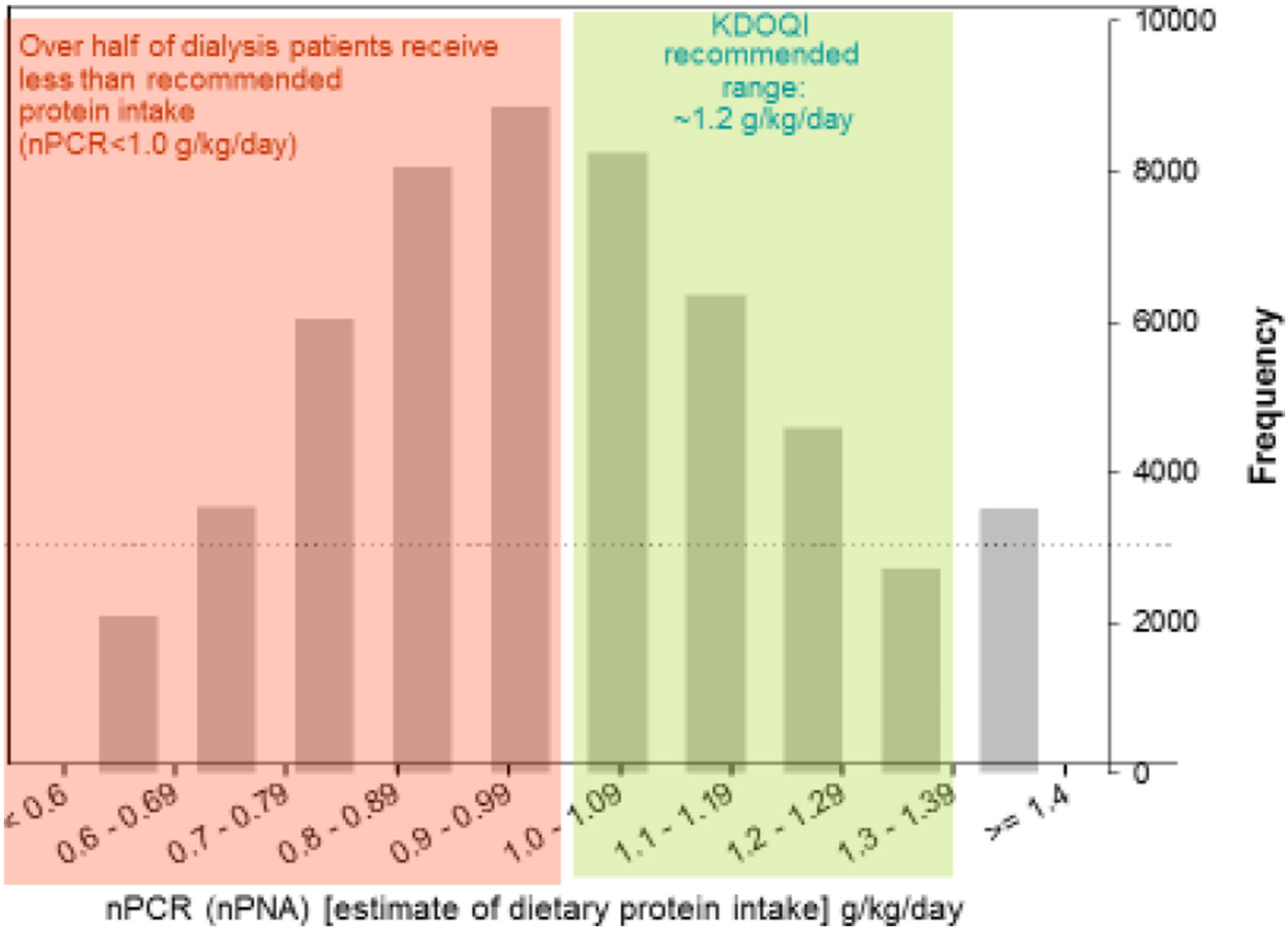

Figure 1.

Frequency of different ranges of protein intake estimated by nPCR (nPNA) in 53,933 hemodialysis patients (adapted from reference 8)[8]

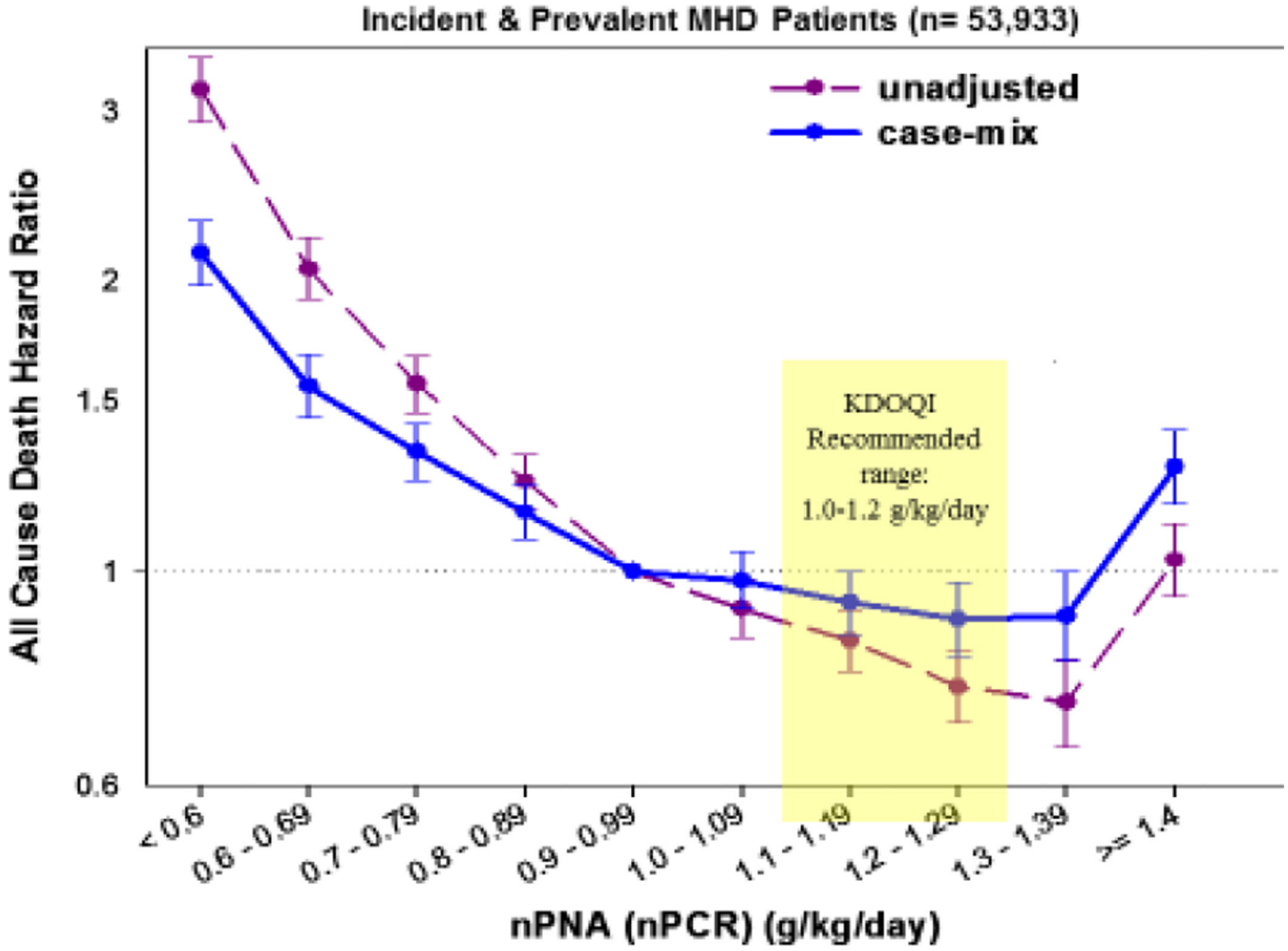

Figure 2.

Associations between dietary protein intake, estimated by nPCR (nPNA) and survival in 53,933 hemodialysis patients (adapted from reference 8)

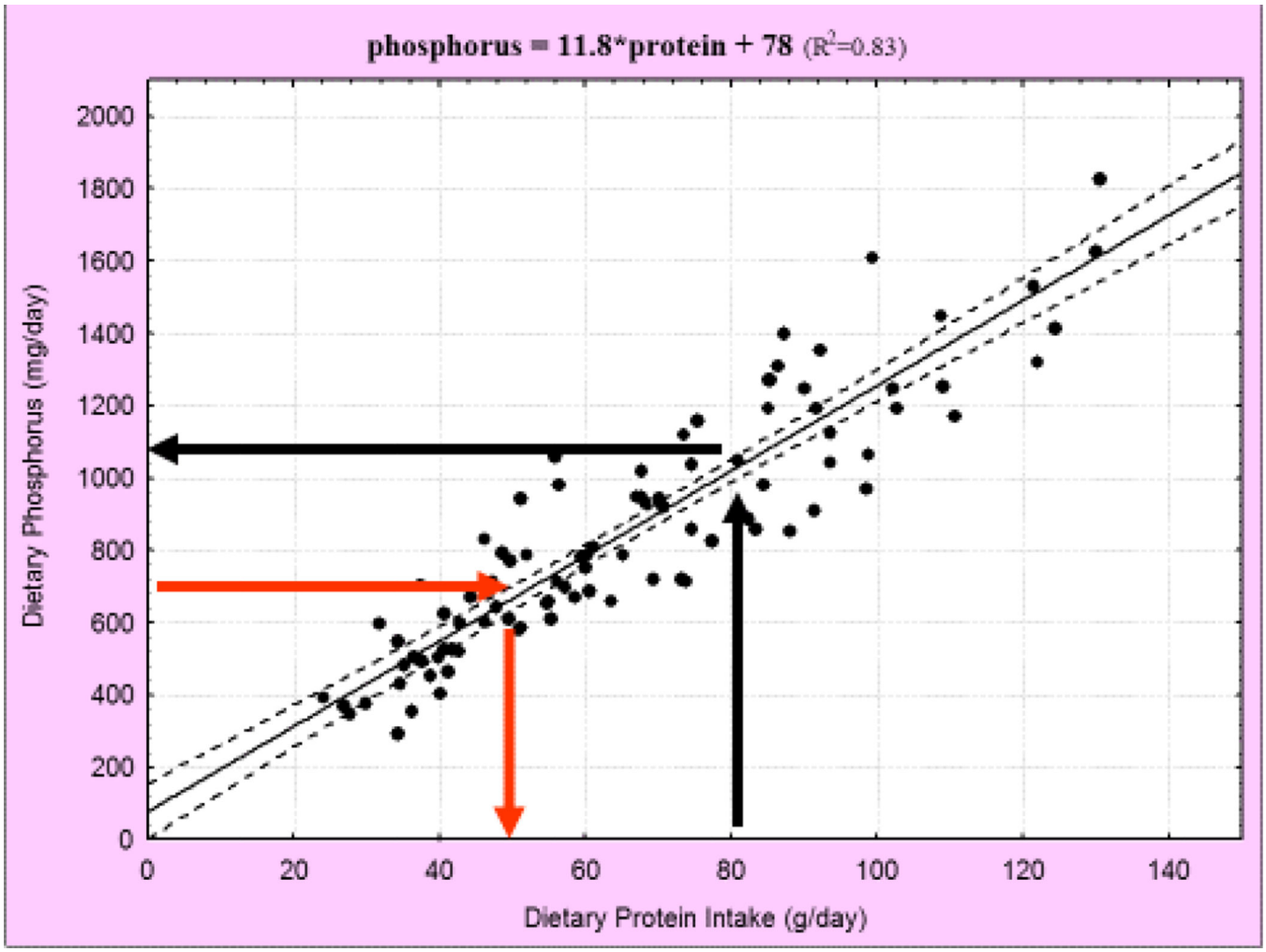

Figure 3.

Correlation between dietary protein and phosphorus content; a recommended protein intake of 1.2 g/kg/day in a 70 kg chronic dialysis patient is equivalent to 85 g/day of protein which exceeds the 800 mg/day phosphorus restriction as shown by the black arrows (adapted from reference 11)

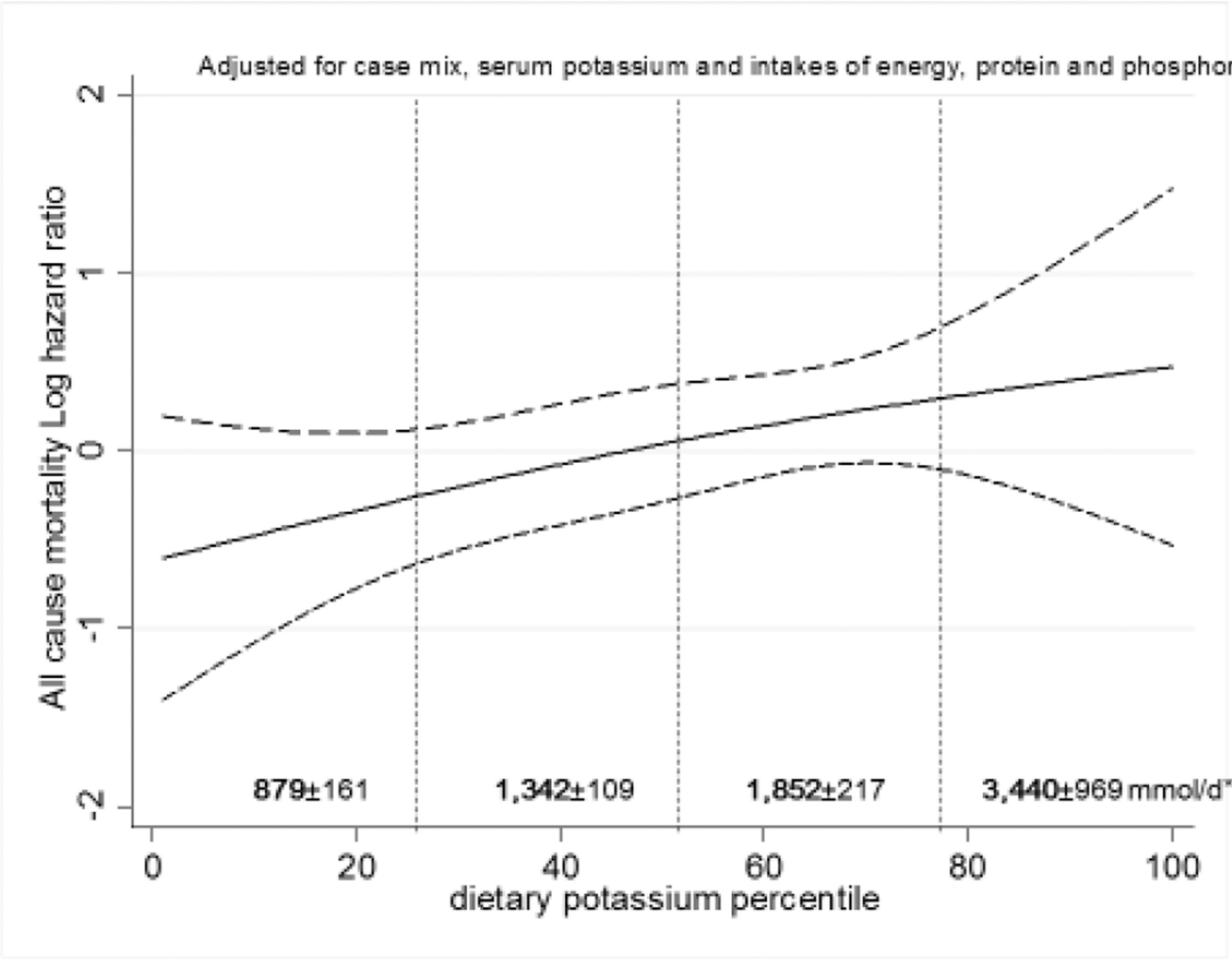

Figure 4.

Association of dietary phosphorus to protein ratio and mortality in hemodialysis patients (adapted from reference 19)

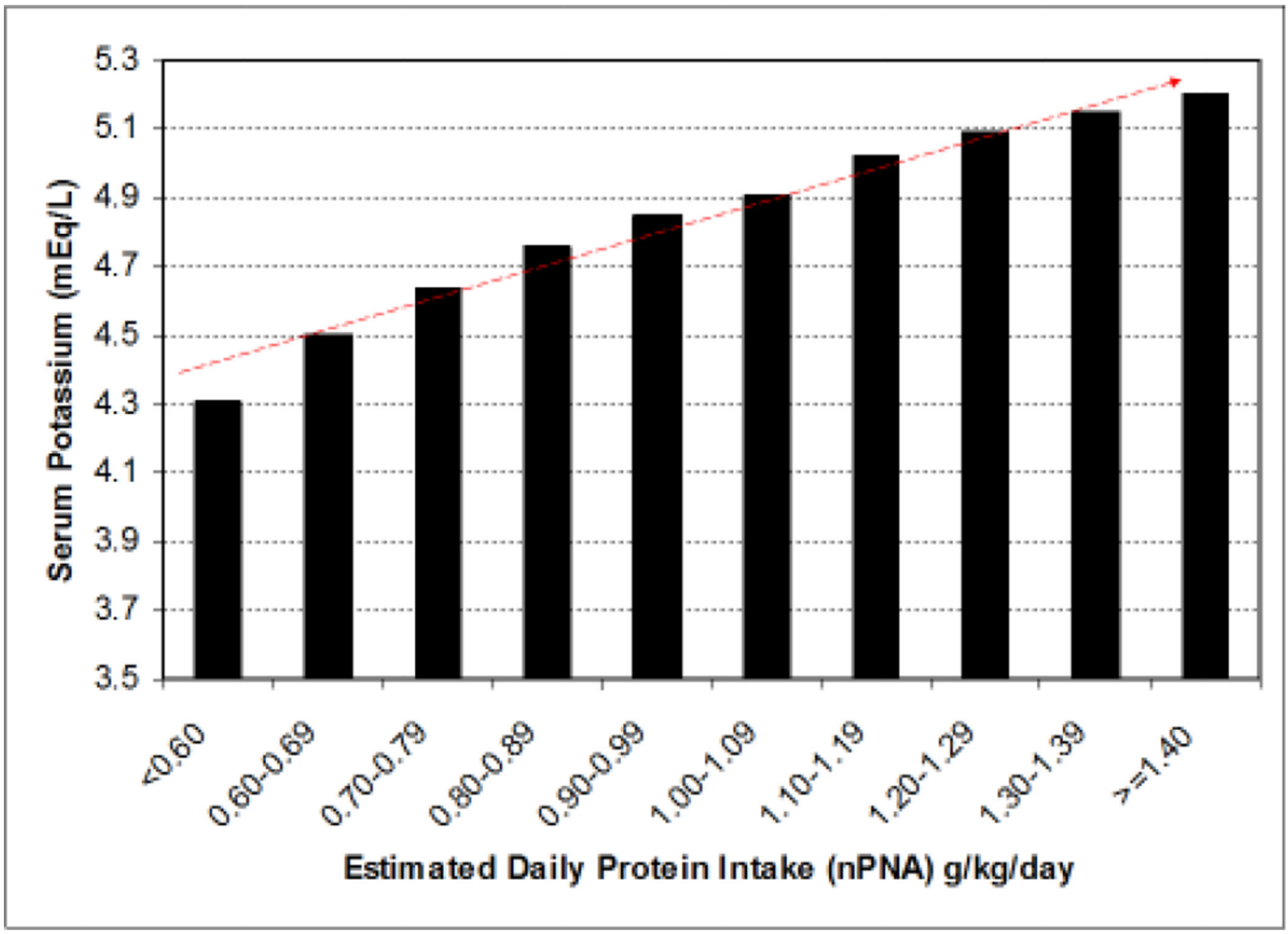

Figure 5.
Correlation between higher dietary protein intake and higher serum potassium level in hemodialysis patients (adapted from reference 27)

Table 1

Dietary recommendations and restriction in dialysis patients and their implications.

	Recommended range	Evidence	Observations
Dietary protein recommendations	1.2–1.4 g/kg/day	Epidemiologic studies show greatest survival with 1.2–1.4 g/kg/day.	Most dialysis patients eat <1.0 g/kg/day.
Dietary phosphorus restrictions	<800 mg/day	Mostly based on epidemiologic association between serum phosphorus and mortality.	Adhering to low phosphorus diet may result in inadequate protein intake.
Dietary potassium (K) restrictions	<3 g/day	Very recent data suggest an association between higher K load and death.	Most K rich foods are heart-healthy.
Dietary salt and fluid restrictions	<2.5 g/day	Salt data are mostly opinion based.There is more recent data on adverse outcomes from fluid retention.	Less fluid intake may be difficult to adhere to if patients are to eat larger amounts of protein and calorie.
Dietary carbohydrate and glycemic restrictions	Mostly for diabetic dialysis patients	Higher A1c >9% may be associated with higher death risk.	May aggravate burnt-out diabetes leading to poor outcomes, especially if A1c<6%.
Dietary lipid restrictions	e.g. DASH diet	Recent data show benefit of Omega-3 and unsaturated fatty acids.	Dietary fat restriction may aggravate calorie malnutrition.
Dietary vitamins and trace elements	Different data	Mixed data regarding vitamin D, and inadequate data for most others.	Some old data suggest certain vitamins such as A should be given with restriction.
Dietary calcium restrictions	<1200 mg/day	Data are mostly based on association between serum calcium and mortality.	Hypocalcemia may be aggravated, especially with calcimimetics.
Meals restrictions during hemodialysis treatment	Meals during hemodialysis	Anecdotal case reports regarding aspiration during hemodialysis while eating.	Hemodialysis induced hypoglycemia.